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Preliminary Assessment Report
Lee v. Moody Bible College

Dear Attorneys:

As per your request, and pertaining to my work in the matter RE: ***Lee v. Moody Bible College***, I have prepared the following ***Preliminary Assessment Report***. Should you have any questions, please do not hesitate to contact me.

Professional Background

My professional expertise is in the areas of engineering physics, mechanics, and safety assessment. I hold the following academic degrees: Bachelor of Science in Engineering, Master of Science in Engineering, and Ph.D. in Engineering. My primary research topics were: safety and accident analysis, risk assessment, and the application of engineering physics and mechanics. My Curriculum Vitae (CV) is attached hereto.

For the past 25 years, I have been called on to provide expert testimony in legal matters involving the application of engineering physics, mechanics, and safety assessment, such as: accident reconstruction, product liability, mechanics of injury, etc. I have been involved in matters for both Plaintiffs and Defendants, before Metropolitan, District, Superior, and Federal Courts.

As of this date, I have approx. 31 years of experience in engineering safety analysis, approx. 31 years of experience in engineering physics and mechanics, and approx. 26 years of experience in accident analysis/reconstruction. Over the years, I have analyzed and/or reconstructed numerous scenarios involving impacts, crashes, energetic events, failures, and defects. I have been involved in projects for forensic clients, private industry, the U.S. Government, and academic institutions. I have also authored over 100 scientific articles in the past 36 years.

Materials Reviewed and Relied Upon

To assist me in my analysis, to date I have received from your office as background information the following materials: (1) National Transportation Safety Board (NTSB) Aviation Accident Factual Report, (undated), 8 pages, and (2) US District Court Order Granting Stipulated Motion to Extend Case Deadlines and Continue Trial (dated 10/16/20), 7 pages. In addition to providing those materials to me, your office also arranged for me to be present during the inspection of the airplane wreckage in April 2021.

As part of my work and analysis of this case, I researched the available literature on the accident in question, as well as reviewed a large number of scientific articles related to physics, mechanics, strength of materials, impacts, bird data, aircraft accidents, bird collisions, windshield tests, etc. There are probably in excess of 100 such articles in my current case file, so for the purposes of brevity, I have not itemized them as part of this Preliminary Report.

Background of the Case

Based on the available information, it is my understanding that this incident occurred on July 13, 2018, at approx. 10:21 am PST. The location of the incident was in rural farmland near Deer Park, WA. The incident involved three individuals (a flight instructor and two student pilots) who were flying in a 2000 Cessna 172R, Registration #: N24442, S/N:17280862. The flight departed from Felts Field Airport near Spokane, WA around 9:55 am, and was tracked by radar for most/all of its flight. At or around 10:21 am, the airplane crashed into the ground, resulting in fatal injuries to all three occupants.

As part of its accident investigation, the NTSB analyzed radar track data, the crash site, the airplane wreckage, autopsies of the occupants, and biological residue from the wreckage. Upon completion of its investigation, the NTSB concluded that the cause of the accident was "birdstrike", i.e., in-flight collision with a bird. The bird that the NTSB identified as the cause of the collision was an American white pelican. The NTSB further noted that 136 American white pelicans were observed within 26 miles of the location of the accident.

Preliminary Assessment of the Case

As part of my work and analysis of this case, your office asked me to estimate the most likely bird impact forces present on the subject airplane windshield, as well as to compare the effects of the bird impact on acrylic vs. polycarbonate windshields. To respond to your requests, I have categorized this Report into 5 (five) different Issues, as presented below.

Issue #1: The physical properties of the American White Pelican

In order to determine the impact parameters of this collision, it is first necessary to know the physical properties of the bird in question. Based on my research, it is my understanding that the American White Pelican (AWP) is classified as a "very large bird", and overall is one of the largest birds in the world.

Its body weight is about 10-30 lbs; its length is about 50-70 in; and its wingspan is about 8-10 ft. An AWP's body is generally made up of bones, meat, feathers, and other organic material, and scientific studies have estimated their overall density as approx. 62-75 lbs/ft^3 (i.e., 1.0-1.2 g/cm^3), or roughly equal to the density of water at standard temperature and pressure (STP). Furthermore, for purposes of analyzing bird impact with airplane windshields, most studies have modeled the birds as resembling a compacted right-circular cylinder (RCC), in this case approx. 50-70 in long, with a length-to-diameter (L/D) of approx. 2:1 or more.

Issue #2: The physical properties of the Cessna 172R windshield

In addition to knowing the physical parameters of the bird involved in the collision, it is also necessary to know the physical properties of the windshield in question. As of the date of writing of this Report, it is my understanding that numerous small fragments of the subject windshield were collected by NHTSA at the accident scene, and cataloged/bagged. During my April 2021 inspection of the airplane wreckage, I evidenced several plastic bags filled with clear/slightly tinted polymer fragments, but in accordance with the general inspection agreement that day, I did not inspect the fragments in detail, nor did I remove them from the bags. It is my understanding that at some subsequent time in the future, all parties in this case will agree on submitting some/most/all of the fragments to an independent testing laboratory for detailed chemical and mechanical inspection. Such an inspection will (hopefully) provide all parties and their experts with the data on the nature of the windshield, as well as its material and mechanical properties.

At this time, absent that specific knowledge, and based on my research to date, I have estimated that the subject windshield was most likely made of some form of acrylic, with an average thickness of approx. 0.1- 0.25 in (based on outward inspection of the bagged fragments).

Issue #3: the estimated impact forces on the windshield

The impact forces between the AWP and the subject airplane windshield can be estimated based on the physical properties of the AWP, the windshield, and the known NTSB data. For conservative purposes, I considered a range of values for all pertinent parameters, including the maximum data points that can associated with this collision. Taking into account the wide range of data points, and estimating the overall impact geometry and impact angle between the AWP and the windshield, I arrived at a range of estimated average impact forces of approx. 8,000-37,000 lbf, or approx. 4-19 tons. This range is consistent with impact forces found in the literature for large bird collisions.

Furthermore, by estimating a triangular impact pulse (as discussed in the applicable literature), we can correlate the estimated average impact forces to maximum (peak) impact forces by applying a factor of 2. Therefore, I would estimate that the maximum (peak) impact forces between the AWP and the windshield would be approx. 16,000-74,000 lbf, or approx. 8-37 tons.

However, in addition to the above values, it is also necessary to consider two factors that may influence the final magnitude of the impact forces: (1) resolution of closing speed with respect to the AWP-to-windshield impact angle, and (2) effects of rotating propeller blades on partitioning of the AWP body immediately prior to impact with the windshield.

By resolving the angular effects of closing speed into components parallel and perpendicular to the orientation of the windshield, and with estimating a roughly 45 degree impact angle (as opposed to a maximum-effect 90 degree impact angle), the impact forces estimated above could be reduced by approx. 29%.

In addition, to consider the effects of the rotating propeller blades, we can estimate a broad range of engine (propeller) speed of 1,200-2,400 RPM. At such rotational speeds, if the AWP were to be incident, length-wise, directly into the propeller blades immediately prior to impact with the windshield, the rotating blades could partition the AWP body into approx. 1-4 pieces. Please note that this does NOT by definition translate into a potential 4x reduction in the impacting AWP mass, i.e., only one quarter of the cut-up AWP body impacting the windshield.

Issue #4: the estimated effects on an ACRYLIC windshield

In the case of an ACRYLIC windshield, the effects of the above-discussed impact parameters can be estimated using published scientific data from bird impact tests. Based on available test data (and focusing on tests involving smaller airplanes and windshields), I would estimate that the thicknesses of acrylic windshields needed to prevent complete penetration of the AWP would be approx. 0.3-1.3 in.

Please note that these are general estimates at this time, as the detailed material and mechanical properties of the subject windshield are not known to me at the time of writing of this Report.

Issue #5: the estimated effects on an POLYCARBONATE windshield

In the case of a POLYCARBONATE windshield, the effects of the above-discussed impact parameters can also be estimated using published scientific data from bird impact tests. Based on available test data (and again focusing on tests involving smaller airplanes and windshields), I would estimate that the thicknesses of acrylic windshields needed to prevent complete penetration of the AWP would be approx. 0.2-0.3 in, i.e., values that are up to several factors lower than the values for acrylic. This is generally in accordance with the difference in published mechanical properties of the two materials, wherein the fracture energies of polycarbonate are approx. 5-30x greater than those for acrylic (depending on source, material configuration, and test method).

Please note that these are general estimates at this time, as the detailed material and mechanical properties of the subject windshield are not known to me at the time of writing of this Report.

CONCLUSIONS

Based on my review, research, and analysis conducted to date, and with the information available to me as of now, I can roughly estimate that, for conservative purposes, a "resistant" windshield able to prevent complete penetration of the AWP would need to be approx. 1.3 in thick (if made of general acrylic) and approx. 0.3 in thick (if made of general polycarbonate).

However, I feel it is quite necessary to interpose a very important caveat here: the above parameters are not only estimates, but are also, for all practical purposes, purely theoretical and also very likely unrealistic when it comes to incorporating them into an actual aircraft.

Specifically, I need to point out that the impact forces in a scenario involving a "very large bird" such as an AWP, and closing speeds around 100 kts +/- (as was the case in this accident), are on the order of tens of tons! Even if a "resistant" windshield were to be designed/constructed to resist such enormous impact forces, we need to keep in mind that the bulk of those forces (and their associated moments) would be transferred to the windshield attachment structures, i.e., the fuselage surrounding the cockpit. Based on my experience, I would expect that when subjected to tens of tons of external forces, such a "resistant" windshield would simply be ripped out of its attachments and blown back into the cockpit, straight into the faces/bodies of the pilots/occupants, and would act like a large, rigid, high-speed missile.

In conclusion, taking all available information, data, and parameters of this scenario into account, it my preliminary opinion that installing a "resistant" windshield as discussed above (regardless of chosen material or associated thickness) would not be a realistic solution to the problem of an in-flight collision with a "very large bird" such as an AWP.

PLEASE NOTE: this ***Preliminary Assessment Report*** is based on information available to me as of the above date. If additional information comes to my attention, I reserve the right to augment, modify, or rescind my opinions, and will so notify.

Respectfully Submitted,

Voyko Banjac

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